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Elastic Tight Device Impact Research on Athlete's Activities

Wu Ji

Sports College, Hunan International Economics University, Changsha, 410205, China

ABSTRACT

To quantify the effects of external compression on the muscular strength, fatigue and activity through electromyography (EMG) and mechanomyography (MMG) during isokinetic muscle actions. The 66.4 N and 85.8 N tension-length curve (used as moderate and high compression, respectively) were obtained with standard weights through a force transducer. All subjects ($n = 12$) performed 5 sec of MVCs and 25 isokinetic knee extensions at 60° and $300^\circ \text{ sec}^{-1}$ with the two different compressions and without compression. The signals for strength production, EMG and MMG amplitude (RMS) were collected simultaneously. No significant differences were found among three compressions for strength production; while there was a significant decrescence in the ratio of torque and overall rmsEMG ($p < 0.05$) during performing isokinetic knee extensions at 60° and $300^\circ \text{ sec}^{-1}$, comparing to the none compression. Local elastic compression on lower extremity did not significantly improve isokinetic strength in a short period of time but did positively affect on muscular fatigue by helping maintain long-term force production through recruiting lesser motor units during movements.

Key words: Different compression, strength, fatigue, electromyography, mechanomyography

INTRODUCTION

With the development of technology and the growing concerns about sports, athlete strength and technique are not just contested in today's sports arena but also is for a variety of high-tech sports equipment show and competition arena. Among them, the tight-fitting equipment (such as tight shorts, tank top, tights, etc.) is not only favored by athletes and sports fans at home and abroad with its unique technology, a wide range of applications and their functionality and it gradually becomes the study hot of the sports field (Li, 2005; Wallace *et al.*, 2006). Currently, by the interpretation of international promotion, the main reasons of athletic performance for the tight-fitting equipment has four points (Herzog, 1993; Kraemer *et al.*, 2001): (1) To promote blood circulation, (2) Changes in kinematic parameters, (3) An increase proprioception and muscle function and (4) To reduce soft tissue vibrations. However, it must be noted that although this series of studies have shown that tight equipment does have a certain influence to athletic performance but its internal mechanism remains unclear and some studies have not found that the presence of tight equipment has similar positive role (Maton *et al.*, 2006; Duffield and Portus, 2007). In addition, domestic movement science in study is almost empty this area, tight equipment research is less on the impact of muscle activity abroad, internal mechanism understanding of for the tight equipment role has been limited.

There are SEMG (Surface electromyography, sEMG) and another emerging non-invasive bio-signal acquisition technology-mechanomyography (MMG) in recent years, which have been widely used as the research tools of muscle function testing and evaluation (Hendrix *et al.*, 2009;

Liu and Peng, 2007; Beck *et al.*, 2005). Meanwhile, the EMG and MMG can be used to study comprehensively muscle internal excitation-contraction coupling and mechanical activity features and then Sports control strategy (motor control strategies) of the neural - musculoskeletal system (Ebersole *et al.*, 2000) is understood. In this study, when people wear tight devices with different tightness, EMG and MMG techniques are used to analyze quantitatively muscle reaction and activities in both sports modes (isometric and isokinetic), additional tight devices is explored to affect the lower extremity muscle strength and fatigue performance and we try to understand the relationship and the internal mechanism between tight equipment and sports performance, while a reference is provided for tight equipment design and its uses.

MATERIALS AND METHODS

Study object: The 12 Athletics male athletes of physical education are selected as research subjects (age 21.2 ± 0.4 years; Height 177.5 ± 4.8 cm; Weight 67.1 ± 6.4 kg; training period 3.0 ± 1.0 years). All subjects received the questionnaire before the experiment, they did not engage in strenuous exercise within 24 h and there is no history of lower extremity injuries in half years, there are a good physical condition and athletic ability and the informed consent is signed with them.

Laboratory instruments

Tight equipment: Sports knee is refitted which is made by a International Motion Equipment Company, whose main material is a polyamide and cotton. It will be cut, sewn into the snap button, so that it can freely adjust the tension (Fig. 1).

Isokinetic strength testing system: Human muscle assessment and training system Con-trex is made by Switzerland CMV AG company. Con-trex human muscle assessment and training system is shown in Fig. 2. The experiment is focused on lower limb knee extensor movement, the isometric and isokinetic muscle strength is tested to the rectus femoris.

EMG signal analysis system: Germany Biovision's EMG-Amplifier system is used which includes electrodes and amplifiers, the electrode material is silver/silver chloride, the amplifier specifications: Magnification is adjustable (1000, 2500 and 5000), input impedance is $10E+2 \Omega$

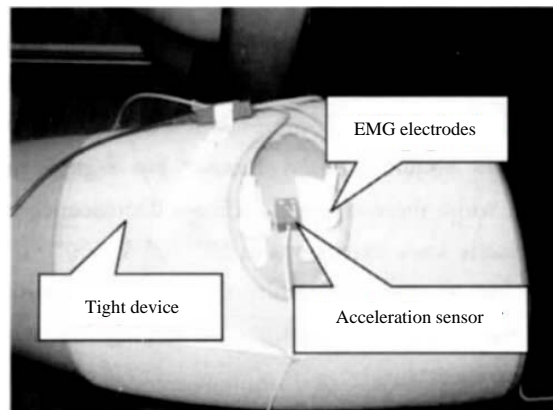


Fig. 1: Attached location map of EMG muscle, EMG electrodes and acceleration sensors



Fig. 2: Con-trex human muscle assessment and training system



Fig. 3: Electromyography amplifier system

CMRR ratio is 120 dB; SNR is 1 μ V. Electromyography amplifier system is shown in Fig. 3. The sampling frequency of the experiment is 1000 Hz.

MMG signal analysis system: Germany Biovision's dual-axis accelerometer is used, measurement range is ± 10 g ($g = 9.81 \text{ m sec}^{-1}$), frequency bandwidth DC is to 1000 Hz, size is 14 mm \times 9 mm \times 5 mm, weight is 4 g. Before testing, Biovision system is connected firstly to the signal input box, Dasy Lab 8.0 software is used to calibrate the X-axis and Y-axis acceleration sensor, the sampling frequency of the experiment is 1000 Hz. Germany biovision sport utility bioelectrical measurement and analysis system is shown in Fig. 4.

Other lab supplies: Inclinator is replaced on at Con-trex power arm and is used to record the angle change in isokinetic process which also includes force sensors, weight, laptops, alcohol, cotton, razors and double-sided adhesive for measuring the tight-fitting device tension.

Test methods and evaluation parameters

Elastic load quantification of tight device: The power sensors and weights are harnessed to measure tension-length curve ($r = 0.99$, $p < 0.0001$) of tight device, secondary and higher tightness load is obtained by the quantify (Fig. 5), when the two tensions are 66.4 and 85.8 N, the corresponding stretched length are, respectively 18 and 24 cm.



Fig. 4(a-d): Germany biovision sport utility bioelectrical measurement and analysis system

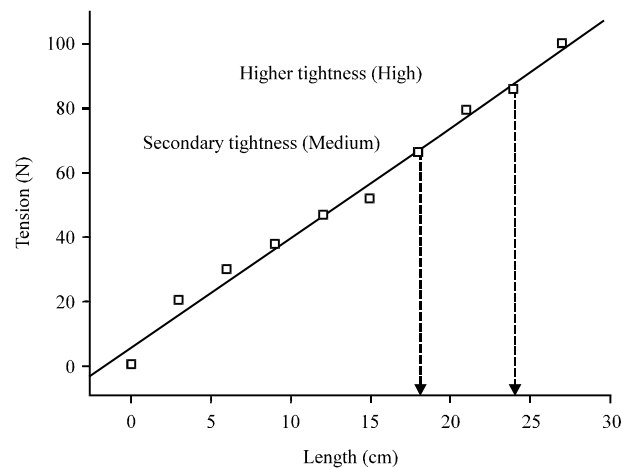


Fig. 5: Tight device tension-length curve

Isometric and isokinetic muscle strength test: Each subject needs to complete three test under tightness conditions which are namely no tight unit, moderate tightness loads and higher tightness load which is tested in random order. Testing time is for 3 consecutive days, a condition is completed every day in the same period of time. Specific steps are as follows: (1) When maximum isometric muscle testing, subjects were seated (knee 60°) and fixed on the isokinetic muscle strength tester, Maximum Voluntary Contraction (MVC) of rectus femoris is for 5 sec at 100%, that is extensor action, (2) In isokinetic testing: Each subject makes maximum efforts separately at low speed (angular velocity of $60^\circ \text{ sec}^{-1}$) and high-speed (angular velocity of $300^\circ \text{ sec}^{-1}$) to complete a total of 25 consecutive centripetal sports with isokinetic extensor. Two speed test interval is 15 min and (3) In the above two muscle strength tests, Dasy Lab 8.0 system is used to collect synchronously the rectus femoris EMG and MMG signals, wherein EMG electrodes and the placed accelerometer are shown in Fig. 1 and the inclination is used to record angle change simultaneously in isokinetic process.

Evaluation of parameters:

- In strength output, there are the relative peak torque (rPT) in isometric contraction phase, the relative peak torque (rPT) in isokinetic centripetal contraction phase, the relative peak power (rPP), the relative average power (rAP) in the first five times and the total amount of work (TW)
- Fatigue performance, is the acting fatigue (work fatigue, WF) and the normalized torque attenuation coefficient (k)

$$WF = W_{(2-4 \text{ works before})} - W_{(2-4 \text{ works behind})} / W_{(2-4 \text{ works before})}$$

The smaller fatigue, the stronger muscle fatigue ability.

When the muscles are doing continuous exercise with maximum isokinetic, the generated torque will show a decreasing relationship with the increasement of the operation frequency (Gray and Chandler, 1989; Perry-Rana *et al.*, 2003). Accordingly, this study adopts torque attenuation coefficient, i.e., the resulting slope k the after linear fit represents the torque output declining trend in the entire isokinetic process, the muscle ability is assessed to work for long hours and to fight fatigue. The 1st extensor peak torque in isokinetic testing is standardized, by using linear regression model, regression coefficients k is determined with 25 consecutive maximal isokinetic centripetal contraction peak torque, torque attenuation coefficient is normalized. As follows:

$$y = kx + b \text{ (Linear model)}$$

where, x represents the number of operations, y is each peak torque. Since the k value is negative, the greater its value, the more it is closer to zero, the stronger the muscles resistance to fatigue.

- Muscle activity performance: During isometric contraction phase and a total of 25 sec class movement, amplitude value of EMG and MMG, Root Mean Square (RMS) are as follow:

$$RMS_{EMG} = \sqrt{\frac{1}{T} \int_t^{t+T} EMG^2(t).di}$$

$$RMS_{MMG} = \sqrt{\frac{1}{T} \int_t^{t+T} MMG^2(t).di}$$

where, t is the signal start time, (t+T) is the signal end time, root mean square (RMS).

Statistical analysis: Each parameter values are by average value \pm standard deviation ($\bar{x} \pm s$), all data were statistically analyzed by using Excel and SPSS software and by independent samples t-test, the differences of the parameters are analyzed under three tightness condition (no, middle, higher), significant level is $p < 0.05$, very significant level is $p < 0.01$.

RESULTS AND DISCUSSION

Strength output: When subjects are in 100% MVC process for 5 sec, under three kinds of no, secondary and higher tightness conditions, their relative peak torque (rPT) is no significant

Table 1: Maximum isometric and isokinetic movement, peak torque (rPT), peak power (rPP), the average power of the former 5 times (rAP) and total work load (TW) are compared under three tightness conditions

Parameters	60° (sec ⁻¹)			300° (sec ⁻¹)		
	No. tightness	Moderate tightness	High tightness	No. tightness	Moderate tightness	High tightness
rPT (Nm kg ⁻¹)	2.63±0.49	2.67±0.45	2.52±0.33	2.08±0.42	2.08±0.23	1.88±0.36
rPP (W kg ⁻¹)	2.74±0.52	2.78±0.48	2.63±0.36	9.17±1.07	9.13±0.97	8.50±1.50
rAP (W kg ⁻¹)	1.61±0.23	1.65±0.28	1.50±0.25	3.48±0.47	3.56±0.39	3.34±0.66
TW (J)	3118.50±608.8	3199.40±533.4	3050.90±591.8	2498.90±430.5	2600.40±360.6	2458.90±512.8

Table 2: When 60° and 300° sec⁻¹ isokinetic centripetal movement, three work tightness fatigue comparison (%) (n = 12)

Parameters	60° (sec ⁻¹)	300° (sec ⁻¹)
No. tightness	25.0±15.7	22.8±10.7
Moderate tightness	27.4±10.7	23.1±8.4
High tightness	23.9±16.1	22.6±16.2

difference (3.34±0.59, 3.16±0.43, 3.21±0.61). At the same time, a total of 25 times continuous extensor isokinetic centripetal movements are completed with the greatest effort at low speed (angular velocity of 60° sec⁻¹) and high speed (angular velocity of 300° sec⁻¹), peak torque (rPT), peak power (rPP), the average power of the former 5 times (rAP) and total work load (TW) are no significant difference (Table 1) under three tightness conditions.

Fatigue performance

Acting fatigue: In low-speed or high-speed conditions, acting fatigue between the three tightness was no significant difference (Table 2), it is noteworthy that the higher tightness is in the angular velocity of both the of 60° sec⁻¹, or 300° sec⁻¹, its fatigue is compared to the both rest of the presence, there is a downward trend but it is not significant differences. In addition, under the same tightness conditions, fatigue at low speed is greater than the speed movement.

Attenuation coefficient of normalized torque: In three conditions of the absence, secondary and higher tightness, when the angular velocity is 60° sec⁻¹, maximum peak torque after normalized appears in the 3rd or 4th course of action, the relationship between the attenuation coefficient is $k_{high} > k_{con} > k_{medium}$. Meanwhile, the angular velocity is 300° sec⁻¹, the maximum peak torque of three tightness are in the fourth operation, the normalized torque attenuation coefficient is the same as the $k_{high} > k_{con} > k_{medium}$. Attenuation coefficient of normalized torque is showed in (Fig. 6a, b).

Muscle activity performance under three tightness conditions: When a subject is in isokinetic 60° sec⁻¹ muscle testing, original signal-time graphs of the measured various parameters is showed in Fig. 7 which include rectus femoris electromyography signal (EMG), mechanomyography signal (MMG) and knee angle signal, extensor centripetal contraction is between the two dashed line.

When the angular velocity is 60° sec⁻¹ and the knee extension is repeated to 25 times, rms EMG shows a decreasing trend with the increase of the additional tightness (from no tightness to higher tightness), there is a significant difference between each two ($p < 0.01$).

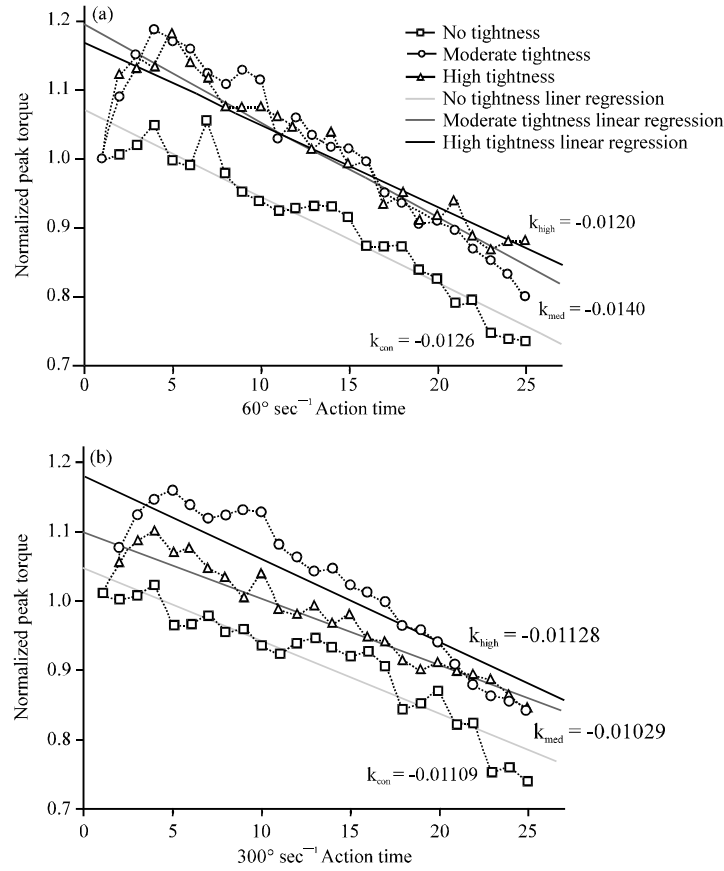


Fig. 6(a-b): Standardized maximum peak torque change map in (a) $60^\circ \text{ sec}^{-1}$ and (b) $300^\circ \text{ sec}^{-1}$ isokinetic centripetal movement

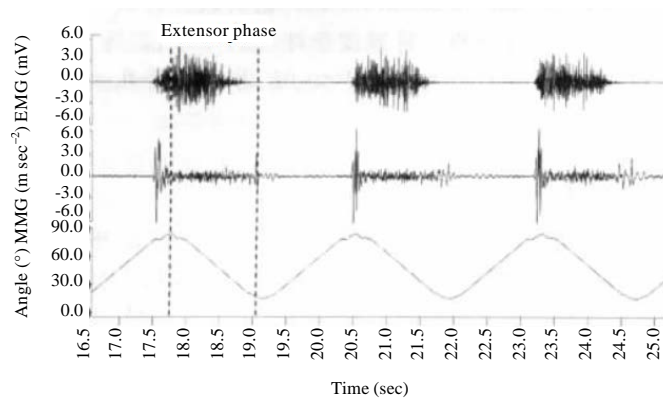


Fig. 7: Original signal-time graphs of the measured various parameters in isokinetic $60^\circ \text{ sec}^{-1}$ muscle testing

In angular velocity of $300^\circ \text{ sec}^{-1}$ and isokinetic centripetal contraction process, the rms EMG values are compared under three tightness conditions, the same as the non-tightness> moderate tightness> High tightness, unless no tightness and moderate tightness are no significant difference

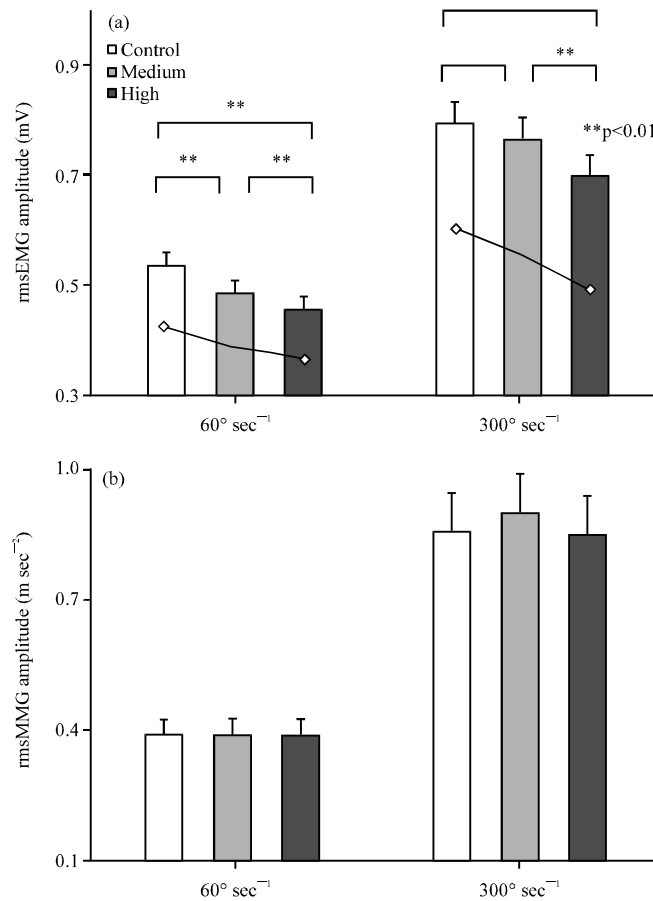


Fig. 8(a-b): (a) EMG and (b) MMG amplitude(RMS) comparison in 60° and 300° sec⁻¹ isokinetic centripetal movement

($p = 0.056$), the remaining is significant differences ($p < 0.01$). Meanwhile, under three tightness conditions, the shares rectus rms MMG value of the 25 times extensor process are no significant difference in terms of 60° sec⁻¹, or 300° sec⁻¹ (Fig. 8).

Tight device which is used in this experiment, did not significantly alter the performance of lower extremity muscle strength and explosiveness but the damping torque is affected to some extent, the muscle is helped to maintain similar strength output in the case of raising fewer Motor Units and thus there is a positive impact to muscle length time work-induced fatigue.

Tight devices are used to reduce the amplitude of the EMG under their state of motion, combined with the present study, under maximal isokinetic centripetal contraction, strength output and torque attenuation results showed that, the plus tight unit is capable of changing Motor Unit activation patterns (MU activation pattern), while an unnecessary muscle activity is decreased, achieving to raise less motor units and to maintain the same output power and thus there is a positive effect on the long fatigue performance. As compared to the previous studies, there are the differences in choice of exercise, such as range of motion and hard mode, additional tightness is no obvious effect on the rectus femoris MMG amplitude, it still needs further study Bringard *et al.* (2006), Houghton *et al.* (2009), Kraemer *et al.* (1998a, b), Nilsson *et al.* (1977), Komi and Viitasalo (1977), Nigg and Wakeling (2001), Wakeling *et al.* (2002), Boyer and Nigg (2006), Doan *et al.* (2003) and Coza and Nigg (2008).

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